Agricultural Research Service • National Program 305 • Crop Production

FY 2016 Annual Report

The Crop Production National Program (NP 305) supports research to develop knowledge, strategies, systems, and technologies that contribute to greater cropping efficiency, productivity, quality, marketability, and protection of annual, perennial, greenhouse, and nursery crops, while increasing environmental quality and worker safety.

The Nation's rural economic vitality depends on the ability of growers to profitably produce and market agricultural products including food, fiber, flowers, industrial products, feed, and fuels, while enhancing the natural resource base of crop production. Future financial success depends on increasing productivity, accessing new markets for specialized products, developing technologies to provide new opportunities for U.S. farmers, and utilizing tools and information to mitigate risks and enable rapid adjustments to changing market conditions. The farm sector has great and varied needs driven by a wide variety of resource, climatic, economic, and social factors that require an equally diverse array of solutions.

Contemporary cropping enterprises are complex and depend on highly integrated management components that address crop production and protection, resource management, mechanization, and automation. U.S. annual, perennial, and greenhouse (protected systems) crop production are based on the successful integration of these components. The development of successful new production systems requires a focus on new and traditional crops; the availability and implementation of improved models and decision aids; cropping systems that are profitable and productive; production methods fostering conservation of natural resources; efficient and effective integrated control strategies for multiple pests; improved methods, principles, and systems for irrigation; improved mechanization; and reduced inputs – all while sustaining or increasing yield and quality.

Production systems must better address the needs of small, intermediate, and large farming enterprises including those using field-, greenhouse-, orchard-, and vineyard-based production platforms with conventional, organic, or controlled environment strategies. Additionally, adaptation and development of technologies are/is required to ensure a sustainable and profitable environment for production agriculture. New technologies must address the need for lower cost, higher efficiency inputs that foster conservation of energy and natural resources, while maintaining profitability and promoting environmental sustainability.

In addition, declining bee populations and honey production require special attention. Over the past several years, a myriad of pests and potentially adverse cultural and pest management practices have been threatening many of the bee species required for pollination of multitudinous crops. Colony Collapse Disorder has increased honey bee (*Apis*) over-wintering mortality to over 30 percent. Also, as new crops or niches are introduced, there is an increasing need for non-honey bee pollinators for specific crops or protected environments.

National Program 305 coordinates and collaborates extensively with other ARS National Programs, universities, and industries in adapting and incorporating technologies, approaches, and strategies that enable the advancement of the Nation's agricultural industry and enhanced international competitiveness.

This National Program is divided into two main research components:

- **Component 1: Integrated Sustainable Crop Production Systems**
- **Component 2: Bees and Pollination**

Below are National Program 305 accomplishments from fiscal year 2016, grouped by research component. This report is not intended to be a progress report describing all ongoing research, but rather an overview that highlights accomplishments, some of which are based on multiple years of research (not all research projects will reach an "accomplishment" endpoint each year).

ARS welcomes your input regarding our ongoing research programs. If you have any questions, please do not hesitate to contact the National Program 305 team, Kevin Hackett (Kevin.Hackett@ars.usda.gov), Rosalind James (Rosalind.James@ars.usda.gov) and Joe Munyaneza (Joseph.Munyaneza@ars.usda.gov).

Component 1 – Integrated Sustainable Crop Production Systems

Remote sensing of glyphosate-resistant and glyphosate-susceptible weeds. The increased use of the herbicide glyphosate has resulted in the development of herbicide resistant weeds throughout much of the U.S, where by 2014, glyphosate resistant weeds had been detected in 38 states. Glyphosate resistant plants cannot be distinguished from glyphosate susceptible plants based on visual examination. However, it is critical that glyphosate resistant plants be rapidly distinguished from susceptible plants, so that the resistant weeds can be controlled with a different herbicide and glyphosate is not applied when it will not result in effective weed control. ARS scientists in Stoneville, MS, conducted greenhouse and field studies on two economically important weeds, Palmer Amaranth and Italian Ryegrass, using remote sensors and a simple handheld sensor. The sensors could distinguish glyphosate-resistant Palmer Amaranth from glyphosate-susceptible Palmer Amaranth at more than 90% accuracy. Glyphosate-resistant Italian Ryegrass could be distinguished from glyphosate-susceptible plants with between 70-80% accuracy. The ability to detect glyphosate resistant weeds with these sensors provides growers with a tool for improved weed management that supports efficient and effective use of herbicides. This will help growers conserve resources while improving weed control and reducing the development of more weeds that are resistant to glyphosate.

Reducing irrigation after harvest is safe for blackberries and saves millions of gallons of water per year. Small fruit growers are facing serious water limitations due to warmer and drier weather conditions, increased regulations, and greater demands for water by other sectors. Last year alone, the small fruit industry lost an estimated $20 million of fruit in the Pacific Northwest due to heat and inadequate supplies of water for irrigation and cooling. ARS scientists at Corvallis, Oregon, in collaboration with scientists at Oregon State University, found that growers could safely stop irrigating their blackberry fields after harvest. Withholding irrigation after harvest has no subsequent effect on yield or fruit quality of blackberry, but can save growers 67,000 gallons of water per acre each year. The strategy also helps the plants to harden off in the fall and reduces the potential for freeze damage to the crop over the winter. These findings provide growers with a new approach to water management that considerably reduces production costs and improves stewardship of limited water resources.

Improving spray application in pecan tree canopies. Effective coverage of tree canopies by fungicide sprays is required for effective disease control. However, little has been known about how tractor speed and spray volume impact the coverage of sprays on tree canopies. ARS researchers at Byron, Georgia, showed that slower tractor speeds and the use of volutes, which increase the pressure of the spray application, improved spray coverage at greater heights in the canopy. These results provide growers with an improved method for selecting appropriate application volumes and speeds when applying pesticides to maximize canopy coverage for improving disease control.

Vulnerability report of pecan as a viable tree crop. The loss of genetic diversity endangers crop viability over time, especially when exposed to various biological and environmental stresses. ARS researchers at Somerville, Texas, and Byron, Georgia, together with collaborators at Texas A&M University, assessed the genetic diversity status of cultivated pecan and its wild relatives. Primary horticultural deficiencies were identified for the various growing regions of the United States. This effort establishes for the first time a baseline of pecan's usable genetic diversity and the diversity potentially available from its wild relatives. The results will guide the future genetic improvement and development of commercial pecan varieties.

Population structure of pecan scab. Recent research indicates the pecan scab fungus is genetically diverse. However, no sexual stage of the pathogen has been identified. Knowledge of how the pathogen reproduces can provide a basis for understanding risk to resistance and improving disease management. ARS researchers at Byron, Georgia, in collaboration with scientists at The Noble Foundation, Oklahoma, located the mating type gene on a recently sequenced genome. Additional collaborative research has confirmed existence of both mating types required for successful sexual reproduction by the pathogen. This new knowledge can be applied to develop improved scab disease management strategies.

Genetic diversity of pecan scab. The pecan scab fungal pathogen adapts to infect resistant pecan cultivars, thereby rendering that resistance ineffective. Knowledge of the pathogen's genetics provides a basis for improving disease management. ARS researchers at Byron, Georgia, used molecular markers to detect genetic variation among isolates of the pecan scab pathogen. The results confirmed earlier studies and provided new insights on diversity, gene flow and relatedness among populations of the pathogen. This knowledge is contributing to the development of improved scab disease management strategies based on the deployment of novel resistance combinations in new varieties of cultivated pecan.

Improving pecan scab disease assessment. Accurate and reliable methods for assessing disease incidence and severity are critical to both disease research and management. ARS researchers at Byron, Georgia, have identified the effects of different sources of error on the quality of assessments of severity of pecan scab disease. These findings resulted in the development of an improved rating system for scientists and farmers to assess the severity of pecan scab disease. The new system promotes improved selection of disease resistant pecans and enhances the accuracy of determining disease severity.

Use of winery wastewater for irrigation in California vineyards. The scarcity of water in California is compelling growers to identify new water sources for irrigating crops. ARS researchers at Davis, California, demonstrated that wastewater treatment produced water that was acceptable for irrigating grapes. The treated water also did not contribute to increasing soil salinity, which is a major problem for agriculture in California. Irrigating grapes with treated water did not have any perceived effects on wine sensory characteristics. These finding indicate that wineries and vineyard operators can check their treated wastewater and determine if the water will have acceptable quality for irrigation. Reuse of wastewater provides a way to produce grapes of high quality that will sustain and enhance the wine industry of California while supporting conservation of limited freshwater resources.

Foliar application of a plant hormone increases grapevine cold hardiness. Wine grapevines of European origin (Vitis vinifera) are often injured or killed by cold weather events in autumn, mid-winter and spring. An ARS scientist in Parma, Idaho, in cooperation with Canadian collaborators and collaborators at Washington and Ohio State Universities, identified concentrations, application timings and formulations of the plant hormone abscisic acid that increased bud cold hardiness by nearly 40°F in the wine grape cultivars Chardonnay and Merlot. Foliar application of a naturally occurring form of abscisic acid advanced the onset of dormancy and increased bud cold hardiness in autumn. Foliar application of a purported long-lived analogue of abscisic acid (8’-acetylene abscisic acid) increased bud cold hardiness and delayed bud break in the spring following application and was most effective when applied after harvest. Wine grape producers use these results to improve cold hardiness of their grapevines and reduce economic losses due to cold injury.

Mechanisms of water absorption and movement by plant roots under drought conditions elucidated. Water first enters plants through fine roots. Under drought, roots are thought to operate like an electrical fuse, which is designed to break, but the exact site and timing of root dysfunction remains elusive. ARS researchers in Davis, California, demonstrated that drought-induced mechanical failure in fine root cells is the primary driver of reduced capacity of roots to move water under mild to moderate drought stress. This mechanical damage coincides with a precipitous drop in fine root permeability. These findings will enable development of precision irrigation strategies tailored to specific rooting traits.

Preventative management of grapevine trunk diseases proven. Grape pest-control advisers (PCAs) recommend preventative practices for trunk diseases. These practices may be used in young healthy vineyards, but more often they are applied only to mature diseased vineyards. Application of these practices demonstrates a gap between published research and farming practices that must be resolved. ARS scientists in Davis, California surveyed growers and found that most growers do not adopt preventative practices until after symptoms are widespread in the vineyard. The scientists calculated the economic impacts of adopting preventative practices in young vineyards, which clearly showed benefits of proper timing before symptoms are widespread. The results were rapidly communicated to growers through new online management plans and a website where growers can compare the returns expected under different preventative practices. These findings promote more effective disease management in vineyards.

Improved management of greenhouse gas (GHG) emissions for the wine-grape industry. Agricultural land contributes to global emissions of greenhouse gases (GHG) but mechanisms by which different crops and management practices emit GHG are poorly understood. ARS researchers in Davis, California, demonstrated that nitrous oxide (N2O) emissions from vineyards subjected to diverse management practices were greatest in response to the first precipitation event of the rainy season in California's Mediterranean climate. In the dry season, large N2O fluxes were related to drip irrigation and fertigation practices, indicating that modifications to such practices may reduce gaseous emissions. The researchers also demonstrated that GHG emissions were limited by soil water availability rather than soil temperature. This study provides valuable data that were used to development COMET-Farm, a practice-based tool to assess GHG footprints. These advances will provide growers with guidelines on how to reduce GHG emissions.

Improving drought stress in plants. Drought is one of the major environmental stresses constraining agricultural production. Plants have evolved diverse strategies to respond to drought, including increasing production of the hormone abscisic acid (ABA). An ARS researcher in Davis, California, in collaboration with researchers at University of California, Davis, have produced transgenic petunias that increase ABA concentrations when exposed to drought stress. The plants were not only resistant to severe drought, but fully recovered when water stress was lifted, and these plants grew like traditional petunias in the absence of drought stress. These results demonstrate an example of the successful modification of plants to improve drought tolerance, and this approach will be applied to develop improved drought resistance in other crops.

Developing partnerships to promote "Climate-Smart Agriculture". Efficiently addressing the impacts of climate change on agriculture requires cooperation among various research groups and agencies. ARS scientists in Davis, California, in cooperation with state government agencies, university researchers, and cooperative extension faculty implemented a strategic plan, secured funds, and recruited and hired critical personnel, including a permanent Director, for the Climate Hub at the University of California-Davis. The California and Southwest Climate Hubs held a joint workshop on impacts of climate change on rangelands, and completed a comprehensive vulnerability assessment of California rangeland involving federal, state and industry partners. The California Hub supported the Southwest Climate Science Summit in partnership with the United States Geological Survey (USGS) Southwest Climate Science Center, and initiated adaptation of the Forest Adaptation Workbook for specific needs in California. Combined, these efforts enhance our ability to deal with climate change in a proactive, science-based manner.

Steel slag can be effectively used as a component in soilless container media to adjust pH and provide beneficial silicon and some nutritional elements. Soilless growing media, typically used in containerized production, generally has a low initial pH and contains minimal nutrition for plant growth. Steel slag, a by-product of the steel manufacturing industry, has been used to elevate field soil pH and is associated with elevated plant nutrition. ARS researchers in Toledo and Wooster, Ohio, demonstrated that media pH can be adjusted utilizing steel slag as a substitute for dolomitic lime in soilless growing systems. In addition, some nutritional benefits can be realized, including elevation of silicon, but these inputs were insufficient to eliminate the use of additional fertilization, especially for microelements. However, with careful management, the use of steel slag could enable greenhouse and nursery growers to reduce fertilizer inputs resulting in less environmental contamination.

PhotoSim developed as a decision-support tool for plant production in protected horticulture systems. Plant photosynthetic rate is impacted by light intensity, CO_2 concentration, and temperature but growers' decisions about these parameters are often made without an understanding of how they impact photosynthetic rate and plant growth. ARS scientists in Toledo, Ohio, developed single-leaf photosynthetic response curves for popular bedding and potted crop species in response to light, temperature, and CO_2. The data were modeled and packaged into a decision-support software tool called "PhotoSim" that provides growers the ability to estimate the impact that changing one of these parameters will have on plant growth, thereby allowing them to better manage the greenhouse or protected horticulture environment, improve plant growth, and reduce production costs.

Component 2 – Bees and Pollination

Spray adjuvants synergize with honey bee viruses, increasing mortality in developing bees. All the causes of honey bee mortality and colony collapse are still largely unknown. Organosilicones are widely used adjuvants in various cropping systems and in industrial applications that increase chemical penetration and spreading. There is evidence that spray adjuvants synergize with honey bee viruses, increasing mortality in developing bees. In collaborative research with scientists at Pennsylvania State University, ARS scientists in Logan, Utah, found that the spray adjuvant, organosilicone, synergized with bee viruses in larval food to increase the amount of virus in the larvae, resulting in bee death during pupation. In almonds, the amount of organosilicone spray adjuvants used in tank mixing and pesticide applications is about the same as the amount of fungicide in use there. Symptoms observed in dying brood that were exposed to organosilicones and viral exposure are similar to those reported by beekeepers who experience elevated colony losses following pollination events in crops such as almonds. These findings identify a previously unknown factor that may be underlying increased colony loss.

A bacterium typically found in the hive environment provides resistance to nosema infection. Nosema, a fungal parasite in the bee gut, is among the most common pathogens affecting adult honey bees and is associated with chronic poor health and colony mortality. Fumagillin, which is a pesticide commonly used to control nosema infection, may be detrimental to the bee and actually increase infection by this parasite. Consequently there is a critical need for alternative strategies for nosema control. ARS researchers at Tucson, Arizona, have identified a naturally occurring bacteria that decreases nosema levels in the gut by approximately 40 percent when fed to bees. The bacteria is being developed for use by beekeepers to protect honey bee colonies from losses due to nosema infection.

Pathological traits have value as predictive biomarkers for Colony Collapse Disorder. The causes of Colony Collapse Disorder (CCD), which results in sick bees and ultimately the destruction of affected beehives, are not well understood. Collaborations between ARS scientists in Logan, Utah, and researchers at University of Maryland and University of Liege in Belgium, have defined four particular pathologies that can be used to predict honey bee colonies with an increased likelihood of undergoing CCD. Identification of these traits provides bee keepers and others with a method to reliably predict the future health of colonies. In addition, the pathologies suggest that CCD bees experience a disruption in excretion and water reabsorption, which provides insights on how CCD may be prevented.

Impacts of improved nutrition on bee disease loads. Honey bees often face limited food availability, requiring beekeepers to supplement their diets. In a collaborative project, ARS researchers in Tucson, Arizona, and Beltsville, Maryland maintained honey bee colonies on either rich or deficient natural diets and screened worker bees for viruses known to cause worker bee mortality. Bees with limited nutrition showed more disease and their colonies ultimately died at a higher rate than well fed bees. These results have been transmitted to beekeepers who have been encouraged to manage forage availability and/or protein supplements in order to maintain bee nutrition.

Fungicide inhibits cellular respiration in honey bees. Honey bees and other pollinators often are exposed to fungicides which are applied to plants in bloom where bees are collecting nectar and pollen. Fungicides control fungal growth by inhibiting basic cellular functions that are shared among broad ranges of organisms. The fungicide Pristine prevents fungal growth by inhibiting cellular respiration and reducing the production of adenosine triphosphate (ATP), a molecule that animals use to convert food into energy. ARS researchers in Tucson, Arizona, found that field-relevant concentrations of Pristine fed to honey bees in pollen inhibited ATP production. Lower bee ATP levels could explain previously reported effects of Pristine on protein digestion and immunity in honey bees since ATP is essential in metabolic pathways associated with these physiological processes. The effect of Pristine in honey bees indicates that this fungicide might not be safe for pollinators when applied where bees are foraging.

Low doses of a neonicotinoid pesticide can affect bee colony behavior and performance. Neonicotinoid pesticides are effective at controlling a wide range of insect pests, but the effects on honeybees of low doses of these pesticides is not well understood. ARS scientists in Tucson, Arizona, and Poplarville, Mississippi, in collaboration with researchers at the University of Arkansas, Mississippi State University and the University of Tennessee, fed sublethal doses of a neonicotinoid pesticide, imidacloprid, for 6 weeks to honey bee colonies. Colonies given 100 parts per billion (ppb) in syrup consumed less than other colonies and had fewer adult bees, less brood, lower weights and reduced temperature control during winter. Counterintuitively, colonies fed 5 ppb imidacloprid showed more activity than other higher-dosed colonies during a nectar flow, so this low dose had a significant positive colony-level effect, a finding which is being further investigated.

Rapid growth of varroa populations in honey bee colonies is due to mites entering hives on foragers. The varroa mite is a serious pest of honey bees and may be the leading cause of colony losses. Varroa mites have relatively low reproductive rates, so populations should not increase rapidly, but often they do. ARS researchers in Tucson, Arizona, determined that mites can enter colonies on foraging bees and significantly increase varroa populations to levels many times greater than from mite reproduction alone. Mites entering colonies on foragers most frequently in the late summer or fall when colonies are preparing to overwinter, which suggests the influx of mites on foragers could be a major cause of overwintering losses. These results indicate that additional mite sampling and varroa treatments may be needed as long as bee foraging activity occurs in the fall.

Impacts of pesticide exposure on honey bee queens. It is not well understood if neonicotinoid pesticides, which are abundantly used to control pests of crops and bees, contribute to poor health of beehives. ARS scientists in Beltsville, Maryland, determined that these chemicals reduced honey bee queen health and longevity. The results provide guidance to queen bee breeders regarding the chemicals that are most likely to impact the health and fertility of the queens they sell.

Nationwide survey of queen bumble bee pathogens reveals potential causes for commercial losses of bumble bee colonies. Bumble bee colonies depend on healthy solitary queens to establish nests in the spring of each year. In commercial colonies used for greenhouse pollination, increased losses are found during production. ARS researchers in Logan, Utah, screened over 300 queen bumble bees from six states for parasites and pathogens. Among the pathogens, the most prevalent pathogen was a protozoan Crithidia bombi that causes low nesting success in queen bumble bees and four viruses, with Black Queen Cell Virus found in nineteen percent of all the individuals. Also notable was the presence of a queen castrating nematode in over seven percent of the queens. These results encourage commercial producers to select for pathogen-free bees to develop more successful colonies and also provide information that is useful to agencies focused on bee health.

Combined impacts of chemical and disease stress on honey bees. Honey bees face significant threats from biological and chemical agents. Among the chemical agents, compounds used to control bee pests and to control pests or microbes on crop plants can inadvertently add to honey bee losses. ARS scientists in Beltsville, Maryland, conducted long-term studies on the interactive effects of chemical and disease stress on bee health. They demonstrated that worker bees exposed to chemicals and mite stress had more diseases and lower survival than bees that were not exposed to these factors. These results provide guidance to beekeepers and regulators that will contribute to the development and maintenance of healthy, productive bees and hives.

Genetic markers associated with chalkbrood resistance were not validated outside of an original mapping population of bees. Marker-assisted breeding would allow for more rapid selection of desired bee traits and accelerated development of improved bees. ARS scientists at Baton Rouge, Louisiana, determined that four genetic markers that were developed from a single population of Russian honey bees were not associated with larval resistance to chalkbrood disease in different populations of Russian bees, varroa sensitive hygience (VSH) bees, or Carniolan bees. These findings indicate the potential difficulty in finding markers suitable for the genetic improvement of honey bees.

Hygienic removal of varroa-infested brood increases the fall of varroa mites to the bottom of a colony. Varroa mites cause millions of dollars of losses annually to beekeepers in the U.S. During the development of disease, mites fall to the bottom of a hive, and the amount of mite fall is an indicator of how well the hive can resist infestation by mites. ARS researchers at Baton Rouge, Louisiana, demonstrated that removing bees infected with mites from the hive resulted in increases in the number of mites that fell to the bottom of the hive. The researchers also observed that Russian honey bees are especially vigilant when it comes to removing infested bees from the hive. These results suggest that removal of infested bees can help reduce the severity of mite infestations.

Almond yield increased by pollinating with Blue Orchard Bees and Honey Bees. Almond yields are largely dependent on effective pollination of trees by bees. ARS scientists from Logan, UT, working in California, tested if the use of both blue orchard bees and honeybees increased almond yields compared to just using honeybees. Results from two years of trials demonstrated that using blue orchard bees along with honey bees increased almond fruit set (average fruit set 67%) compared to use of only honey bees (average fruit set 30%). Overall nut yield increased in many of the plots with both blue orchard bees and honey bees. These results indicate that there is much promise in using blue orchard bees for both maximizing orchard yields and helping to decrease the demands on honey bees.

A new manageable pollinator for the southeastern United States. Obtaining strong commercial colonies of honey bees for crop pollination is becoming increasingly difficult and expected to detrimentally affect sustainable U.S. food production unless alternative pollinators become available. ARS researchers in Poplarville, Mississippi, Stoneville, Mississippi and Logan, Utah, surveyed and tracked the spread of an accidentally introduced bee from Asia. The bee, commonly known as the giant resin bee, visits many exotic trees growing in the southeastern U.S. where this bee uses dilapidated wooden structures for nesting. The scientists discovered giant resin bees readily nested in cardboard bee nesting tubes intended for gathering blue orchard bees. These observations indicate that the giant resin bee should be included on the growing list of manageable native bee crop pollinators, and provides American agriculture with an alternative pollinator to ensure food security.

Cryopreservation of bee semen in a newly developed medium. Increasingly, cryopreserved semen (semen stored in liquid nitrogen for indefinite storage) is used to inseminate queen bees. Although semen transferred during mating (i.e., non-cryopreserved semen) lasts for the lifetime of a naturally fertilized queen, cryopreserved semen is not stable. A dilution medium for bee semen developed by ARS scientists in Fargo, North Dakota, was converted by the scientists into a cryoprotective medium with the addition of an antifreeze (dimethyl sulphoxide). With the newly designed cryoprotective medium, the scientists were able to obtain viable bee sperm cells with an average viability of >94%. This is a significant advancement in the field of semen cryobiology and will form the foundation for the National Bee Gene Bank at Ft. Collins, ensuring preservation of this vital agricultural resource.

Patent issued for bee attractant to increase blue orchard bee nesting and production. The decline of honeybee colonies throughout the U.S. has increased the need for identifying other bee pollinators. The Blue Orchard Bee can be used for managed pollination of many nut and fruit crops. One major hurdle in its use has been getting reliable nesting within the orchards. An attractant has been discovered and patented (Patent # US9301521) for the Blue Orchard Bee by

ARS scientists in Logan, Utah, and Fargo, North Dakota, along with commercial companies. Nesting boxes can be sprayed with the attractant to increase the number of bees using the box and help ensure reliable crop pollination.